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STUDIES IN INDIAN FIBRE PLANTS

No 2. ON SOME NEW VARIETIES OF *HIBISCUS CANNABINUS*, L. AND *HIBISCUS SABDARIFFA*, L.

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PREFACE.

THE improvement of crops in India in which cross-fertilization takes place is attended with considerable difficulty. These difficulties not only concern the production of an improved type at an Experiment Station but also interfere with the maintenance of the quality both on the seed farms and also in the cultivators' fields themselves.

In 1906, a detailed study was undertaken of the fibre plant *Hibiscus cannabinus*, L., which, like cotton, cross-fertilizes to some extent and in which uniformity of fibre is also essential. The results obtained are described in the present paper. It has been found that the ill-effects of vicinism can be almost entirely prevented in this crop by utilizing the differences between the various types which occur in the seedling and early vegetative stages. It is probable that similar methods can be applied to cotton and possibly also to other Indian crops in which natural crossing takes place and in which propagation from single plants is attended with difficulties.

PUSA,
December 16th, 1910.

ALBERT HOWARD.
GABRIELLE L. C. HOWARD.

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I. *HIBISCUS CANNABINUS*, L.

1. Introduction.

Hibiscus cannabinus, Deccan or ambari hemp, is perhaps the fibre plant in India most widely cultivated for local consumption. It does not appear to be grown to any great extent in other parts of the world.[1] This crop, owing to its distribution over the whole of India, is known under a very large number of vernacular names, e.g., *ambári*, *ambadi*, *pulu*, *mesta pát*, *dare kudrum*, *pátsan*, *sheria*, *gogu*, *pundi*, *sujjádo* and *sankukra*.

It is usually cultivated as a mixed or border crop except on the East coast of Madras and to some extent in the jute-growing Districts of Bengal where it is grown pure. In Madras[2] its cultivation is firmly established in the Vizagapatam and Guntur Districts where the area under this crop is about 60,000 acres or six-sevenths of the total acreage in the Presidency. A mill for spinning the fibre and manufacturing it into gunnies has been worked for some years

[1] Dodge, *Descriptive Catalogue of useful Fibre Plants of the World*, Washington, 1897, p. 192.
[2] *Proceedings of the Board of Agriculture in India*, 1909, p. 55.

at Bimlipatam in the Vizagapatam District and another mill has recently been opened at Ellore in the Krishna District. Besides its use as a fibre crop the young leaves and shoots are sometimes eaten as a vegetable.[1] In Bombay and the Central Provinces it is grown to a considerable extent, usually as a mixed crop, while on the alluvium of the Indo-Gangetic plain in Bihár, the United Provinces and the Punjab it is commonly seen in the *Kharif* only on the borders of fields.

The first condition for the successful cultivation of this crop in the alluvium is a well-drained and well-cultivated soil. In the growth of this plant at Púsa during the past four years the effect of local waterlogging has been most marked. In such situations the plants remain stunted and usually die before forming flowers and seeds. The leaves are small and narrow and the root development is exceedingly poor. Want of aeration of the soil has a similar ill-effect to that of waterlogging. This is particularly noticeable at the end of the monsoon when crops which have done well up to this time often show signs of wilting. In such cases unless the soil is immediately cultivated the plants die off. On the other hand they immediately revive when the soil is aerated. Under favourable conditions and especially when grown on high-lying freely draining soils which have been stirred from time to time the crop is tall and vigorous and large crops of good fibre are obtained. It is possible that the extreme sensitiveness of this crop to local waterlogging and want of aeration in the alluvium is the reason why it is grown as a border plant on the edges of fields where the soil is slightly raised and better drained than the rest of the land. If the cultivation of this crop is ever taken up in the plains on a large scale for fibre purposes waterlogging must be prevented and the necessity of frequent cultivation, especially after the monsoon, must be insisted on. Except for these two points the cultivation is simple and the best results

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[1] Roxburgh, *Oriental Plants*, Vol. II, p. 68.

are obtained if the crop is sown on the early monsoon showers of June.

The crop is harvested in Bihár in November when the first formed seeds are just ripe and while the upper portion of the plant is still in flower. There seems to be some difference of opinion as to the exact period when the strongest fibre is obtainable. Roxburgh[1] found that cord made from plants in flower broke at 115 lbs. while that from plants in fruit broke at 110 lbs. Watt,[2] on the other hand, states that "full-grown plants which have ripened their seed furnish stronger fibre than if cut while in flower." The plants are retted in water for ten days or more according to the temperature. At first, the bundles are placed vertically in water to soak the thick root ends only after which they are laid horizontally and completely immersed.

The fibre thus obtained is much more glossy and lighter in colour than *sann* but is harsher and the fibres adhere more closely to one another. The following description of the fibres is taken from Hanausek's *Microscopy of Technical Products.*

Gambo hemp.[3]

"The fibres are yellow-white to grey-yellow, slightly lustrous, somewhat lignified. On treatment of a cross-section with iodine and sulphuric acid, it is evident that the lignification is not uniform throughout. In many fibres the walls are yellow, with a rather brown outer lamella; in others the inner layers of the walls are deep blue, only the outer lamella being yellow. Whole fibres treated in the same manner also show irregularities in colour. These differences may explain some of the contradictory statements of different authors. Wiesner[4] states that the bast cells on treatment with iodine and sulphuric acid swell and become

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1 Roxburgh, l. c.

2 Watt, *The Commercial Products of India*, London, 1908, p. 630.

3 T. F. Hanausek, *Gambohanf. Realenzyklopädie d. ges. Pharm.*, 2. Aufl. 1905. 5, 511, v. Hohnel: *Mikroskopie der technisch verwendeten Faserstoffe*, Wien. 2. Aufl. 1905, 56. Matthews, *Textile Fibres*, New York, 2nd Ed., 1907, 303.

4 *Die Rohstoffe des Pflanzenreiches*, Leipzig, 2. Aufl. 1903, 2, 31.

indigo blue, even to the innermost layers, while v. Hohnel notes only a yellow coloration. v. Hohnel[1], however, employed dilute sulphuric acid, which does not give a blue coloration.

Microscopic structure. The technical fibres consist only of bast fibres. These are up to 6 mm. long, 14-16μ (according to v. Hohnel mostly 21μ) broad, and are either blunt, sometimes with a very short lobe near the end, or else pointed, the walls at the ends being in both cases very strongly thickened. The lumen in one and the same fibre shows very great variation in diameter, in some parts it is broad, in other parts narrow, and in still other parts disappears entirely. Frequently it is alternately broad and narrow. In cross-section the fibres are seen to be closely united, and are either polygonal with sharp angles and straight sides or rounded polygonal with sharp angles and oval, the lumen in the first case being usually small, often a mere point, in the latter case large and oval. Cross-sections examined in water show a broad, distinct outer lamella, but concentric rings are evident only in some of the angular forms and in those but indistinctly.''

Most of the fibre produced in India is used locally, and is mainly employed in making the string and cord necessary for agricultural operations. Coarse sack cloth and canvas are made from it in some parts as well as fishing nets and paper. The export trade in this article is comparatively recent as Royle[2] in 1855 stated ''Though so generally cultivated, its fibre is hardly if at all known as a distinct article of commerce.'' It has since, however, been introduced into the English market under the name of Gambo hemp, fibre of the Roselle and jute of Madras. It also occurs as an admixture to *sann* and other Indian fibres. It is stated that some years ago this fibre was put on the English market under the name of Bimlipatam jute[3] and commanded a good price; £11 to £12-10 a ton. According to Watt[4] the demand for Bimlipatam jute is steadily increasing, the export value in

1 *Mikroskopie der technisch verwendeten Faserstoffe*, Wien. 2. Aufl. 1905, 44.
2 Royle, *The fibrous plants of India*, 1855, p. 257.
3 *Agricultural Ledger*, 1903, No. 2.
4 Watt, l. c.

1903-04 being 2 lakhs of rupees. Wiesner[1] considers that the fibre, if more carefully prepared, might give a useful product and lays stress on the fineness of the fibres. The crop is an easy one to grow and is widely distributed in India so that if a good price could be obtained in London there is no reason why an export trade should not be maintained.

2. Pollination and natural cross-fertilization.

In 1906, five samples of seed of this crop were obtained from Madras by the Fibre Expert to the Government of Eastern Bengal and Assam. Three were named, *paddy gogu*, vegetable *gogu*, Ongole *gogu*, and two samples from Coconada were unnamed. These were handed to us for botanical examination and were sown in the botanical area at Púsa in July of that year. These five samples proved to be mixtures of several distinct varieties, some of them being so different as to suggest a mixture of species. Purple stemmed plants with entire leaves, green stemmed plants with similar leaves, and purple and green stemmed plants with divided leaves as well as other less distinctive forms were found. The same varieties occurred in all the plots and no great differences could be found between the plots as a whole. In 1907 two more samples of seed were sown, Bengal *patsan* and *desi patsan* from Lyallpur but no new forms were detected. The crop as grown in Bihár and in many parts of Northern India appears to be generally of one variety, a green stemmed type with green palmately divided leaves.

Seed (produced under bag and also from free-flowering plants) of all the forms identified was collected from several individuals. The seed of each plant was sown separately the following season. Some of the cultures thus obtained were uniform and resembled the parents in every respect, but from some of the unbagged seed the progeny was not uniform, for example, seed from an entire leaved plant gave both plants with entire and with divided leaves.

[1] Wiesner, l. c.

Mixed cultures of this crop can often be detected in the seedling stage. It was found that great care was necessary in thinning to prevent the coolies and boys from removing all the seedlings which differed from the bulk of the culture. If left to themselves they invariably removed everything which differed from the bulk of the culture and so unconsciously rogued the plots. It was necessary to watch the thinning of the cultures personally and to point out which plants were to be removed.

Every year cultures obtained from single free-flowering plants were mixed and often contained individuals which differed from any of the types in cultivation at Púsa. In 1909, seed from a large number of aberrant plants found in these single plant cultures were collected and the seed of each plant was sown separately. In every case the progeny was mixed. On the other hand in 1910 no case of splitting was observed when seed of the types described in the present paper was obtained under bag and sown. Cross-fertilization in this species is therefore very common when the various forms are grown next to next and allowed to flower freely. A study of the methods of pollination in this crop shewed that the opportunities for cross-pollination by insects are very great.

The flowers of this species open in the early morning before daybreak and begin to close about midday. The closing of the flower is fairly rapid and before sunset the partially withered corollas are twisted up in the manner shown in Plate I. During the night still further twisting of the corolla takes place, giving rise to the cottage loaf shape of the withered flower shown opposite.

The method of pollination of the flowers of this species is of considerable interest and does not seem to have been previously studied in detail. When the flowers open, the stigmas are at the mouth of the staminal column and the anthers have not yet commenced to burst. Soon after daybreak, the stigmas still remain flush with the opening of the column. After this the turgidity of the filaments falls off and the burst anthers bend back towards the

THE POLLINATION MECHANISM OF HIBISCUS CANNABINUS.

PLATE I.

column. Simultaneously the styles elongate and carry the stigmas into the air beyond the opening of the column and at this stage pollen grains are rarely seen on the stigmas. Sometimes, however, the styles bend outwards and carry the stigmas on to the pollen, thus bringing about self-pollination. Frequently no pollen is seen on the stigmas when the flowers begin to close about midday. If closed flowers, however, are opened carefully it is found they are always well pollinated. Self-pollination is effected almost entirely by the closing of the corolla. The limb of the petal is thin, the claw very thick. The corolla closes by the falling towards the centre and twisting of the thin limbs. This brings the corolla in contact with the burst anthers and the completion of the closing of the flowers covers the stigmas with pollen.

It will be seen that the flowers are adapted both for cross and self-pollination. From the time the styles begin to carry the stigmas beyond the opening of the column to the closing of the flower crossing is possible. Self-pollination, however, may also occur during this period. A sufficient supply of seed is ensured by the very effective method of selfing when the flower closes.

The flowers of this species do not set seed under bag in the ordinary way unless artificially self-pollinated. This is due to the fact that the flowers do not close normally in the bag. The thin limbs of the corolla do not fall together and twist in the usual manner, possibly on account of the even humidity of the air both outside and within the closing corolla.

The production of a sufficient supply of selfed seed from a single plant in this crop is an exceedingly tedious operation. It has already been stated that the flowers do not set seed under bag in the ordinary way on account of the failure of the closing mechanism of the corolla under such conditions. The flower buds have to be bagged singly in the evening and selfed the following morning about 9 to 10 A.M. when the anthers are ready to burst the moment the bag is removed. Except when grown singly or at the edges of a plot this crop does not branch much. As the flowers usually open singly and are borne in acropetal succession on the main

stem only one flower can be selfed every day. After setting the bag is moved upwards above the young capsule and if care is taken a succession of selfed capsules can be obtained on the stem one above the other. The short peduncles, however, are exceedingly brittle and inelastic and if damaged the capsules drop.

In order to distinguish the selfed capsules from any free-flowering ones produced after the self-pollinating process is over it was necessary to adopt a special procedure. Labels tied on in the ordinary way just below each selfed capsule were unsatisfactory as they frequently worked loose and slipped down the smooth stem, especially when the plants drop their leaves as the ripening process proceeds. Each selfed capsule was indicated by passing a thread to which a small light card-board label was attached through the stem by means of a needle just at the insertion of the peduncle. At harvest time no difficulty was experienced in reaping the selfed capsules and in rejecting the free-flowering ones. In this way a great saving of time was possible and it was not necessary to visit the plants periodically to remove any subsequent flower buds and to readjust labels.

3. The varieties of H. cannabinus.

Mention has already been made of the fact that among the pure line cultures obtained from selfed seed several different varieties were found. In all, five varieties comprising eight agricultural types, have been isolated. These differ from one another in many particulars and a detailed description of each type with a coloured plate of one type of each of the five varieties is given below. As far as we have been able to ascertain in the literature at our disposal none of these types except the common form (Type 7) with divided leaves and green stems have been described previously. The main differences between the types may be seen from the following summary :—

1. Var. *simplex*.

Type 1. Stems purple; leaves entire with purple petioles. (Plate II.)

Var. *simplex.* Var. *viridis.*

VARIETIES OF H. CANNABINUS WITH SIMPLE LEAVES.

PLATE II.

Var. *vulgaris.*

Var. *ruber.*

Var *purpureus.*

VARIETIES OF H. CANNABINUS WITH DIVIDED LEAVES.

PLATE III.

2. Var. *viridis*.

Type 2. Stems green; leaves entire with green petioles. (Plate II.)

3. Var. *ruber*.

Type 3. Stems red below, greenish above; leaves divided with green petioles. (Plate III.)

4. Var. *purpureus*.

Stems purple; leaves divided with purple petioles.

Type 4. Late, stems very tall and slender; leaves with narrow lobes of a diffused purple colour; petals purplish. (Plate III.)

Type 5. Early; stems short and robust; leaves green with broad lobes.

5. Var. *vulgaris*.

Stems green; leaves divided with green petioles.

Type 6. Plants very early.

Type 7. Plants late; seedlings with reddish stems. (Plate III.)

Type 8. Plants late; seedlings with green stems.

The following is the description of *H. cannabinus* as given by Hooker in the *Flora of British India*.

"*Hibiscus cannabinus*, L. DC. *Prodr.* i, 450; annual or perennial, prickly, stem glabrous, lower leaves entire, upper lobed, midnerve glandular beneath, peduncle very short, bracteoles 7-10 linear, shorter than the calyx, sepals grandular. *Cav. Diss.* iii, 148, t. 52. f. 1; Roxb. *Fl. Ind.* iii, 208; *Cor. Pl.* i, t. 190; *Wall. Cat.*, 1898; *W. & A. Prodr.* i, 50; *Thwaites Enum.* 26; *Dalz. & Gibs. Bombay Fl.* H. Wightianus, *Wall. Cat.* 2695 and 1898.

Generally cultivated; apparently wild East of the Northern Ghats. Distrib. *Cultivated in most tropical countries.*

Stem glabrous, prickly. *Lower leaves* cordate, upper deeply palmately lobed, lobes narrow, serrate; petiole prickly, lower much longer than the blade. *Stipules* linear, pointed. *Peduncles* axillary, very short. *Sepals* bristly, lanceolate, connate below the

middle, with a gland at the back of each. *Corolla* large, spreading, yellow with a crimson centre. *Capsule* globose, pointed, bristly. *Seeds* nearly glabrous. All parts agreeably acid. The stems furnish fibre. The specimen of *H. Wightianus* in Wallich's herbarium is imperfect, but it is doubtless referable to this species; its leaves are simple."

This description refers to the green stemmed form with divided leaves so common in Northern India. This is the form always referred to in the literature published up to the present and is figured in Roxburgh's *Coromandel Plants*. In his concluding sentence Hooker mentions a form with simple leaves. This is the only allusion in the literature to the occurrence of distinct varieties in this species. It appeared to us almost incredible that such well-marked types as the purple stemmed form with entire leaves (Type 1) and the purple stemmed form with divided leaves (Type 4) should have escaped attention, considering that the value of *H. cannabinus* as a fibre plant is discussed and the plant described in all the modern and also in the older books dealing with Indian economic plants. A search was therefore made in the literature at our disposal and the collections in various herbaria were examined to see if the rarer forms of this species, which differ very much from the form described in the *Flora of British India*, had been recorded under other names. Through the courtesy of Major Gage, I.M.S., we were able to examine the specimens of the genus *Hibiscus* in the Calcutta Herbarium and also the valuable collection of coloured drawings. The Reporter on Economic Products to the Government of India kindly sent us the herbarium specimens of the genus in the India Museum, Calcutta, and all the information on the subject at his disposal. While on special duty in England during the current year (1910) we examined the collections of the Linnean Society of London.

Neither descriptions nor specimens of the new types could be found under any other species of *Hibiscus*. The only reference to aberrant forms found in the literature is the one quoted above from the *Flora of British India*. Herbarium specimens of a few

of the types are to be found in the collection at the Indian Museum but they are designated *H. cannabinus* with no comment, except in one case when there is a note on a specimen with a purple stem and divided leaves to the effect that "green and intermediate coloured plants are intermixed. In fact there is no distinction into two races."

It appeared at first probable that the specimen referred to by Hooker as *H. Wightianus* might prove to be either type 1 or type 2 and, through the kindness of Major Gage, herbarium specimens of the types isolated by us were despatched to Kew for comparison with this specimen. The following reply was received :—

H. 330-10 Royal Botanic Gardens,
Kew.

"The Director of the Royal Botanic Gardens, Kew, presents his compliments to Major A. T. Gage, I.M.S., and begs to inform him that the specimens of *Hibiscus* received are not identical with *H. Wightianus*, Wall. The leaves of Wallich's 2695 are much more coarsely and deeply serrate and their petioles are much shorter than those of the specimens received. The stem of *H. Wightianus*, it may be added, is whitish."

In 1910, while on special duty in England, we had the opportunity of examining Wallich's specimens at the Linnean Society. In addition to the information in the above letter it was observed that the epicalyx of *H. Wightianus* is of a very different form to that of any of the types isolated by us. It is much longer, rounder, more spreading and covered with hairs while all the Púsa types have short stiff glabrous epicalyces. It is evident, therefore, that types 1 and 2 are not referable to *H. Wightianus* which, indeed, appears to differ so materially from *H. cannabinus* as to deserve recognition as a separate species. Another specimen from the same collection, namely, Wall. No. 1898, which was referred by Masters to *H. Wightianus*, differs still more markedly in the form of its epicalyx, the lobes of which are expanded at the apex and

different from those of *H. cannabinus* & *H. Wightianus*. By the kind permission of Dr. Jackson we were enabled to have photographs made of both these specimens and these are reproduced in Plate IV. A comparison of these with the coloured plate of the Púsa types will make these differences clear.

The new forms isolated at Púsa must, therefore, be regarded as hitherto undescribed varieties of *H. cannabinus*. We consider it better to class them all as varieties and not to make any new species. In spite of the difference in the leaf form varieties 1 and 2 resemble the ordinary *H. cannabinus* so closely and cross so easily with it that it would seem inadvisable to separate them. The differences between types 6, 7, 8 and between types 4 and 5 are not of the nature of varietal differences and these forms have, therefore, been designated as agricultural types.

There are considerable differences between the eight agricultural types. Type 4 is too delicate for growth in the plains, while types 3, 6 and 7 are likely to be more useful for fibre than the rest. Type 7 is the common form of the plains and is fairly robust. Type 6 is very promising on account of its earliness and straight unbranched stems. It would be possible to harvest this crop in time for a succeeding *rabi* crop. Type 3 is the most vigorous of all. It produces very tall straight and stout stems and thrives well even under defective cultivation. It appears to be a very promising type for Northern India. Experiments are in progress at Púsa to compare the yield and quality of the most promising types when grown in pure culture, and if type 3 fulfils its early promise the introduction of this kind into cultivation would be a distinct improvement.

4. Description of the Types.

The main distinctions between the varieties have already been indicated, but there are in addition many interesting minor points of difference. The following description is common to all the eight types.

WALL. No. 1898.

WALL. No. 2695. H. WIGHTIANUS.

PLATE IV.

Annual, *leaves* midnerve glandular beneath, petiole prickly, long; *stipules* linear, pointed; *flowers* axillary, open for a few hours only; *peduncles* axillary, very short; *epicalyx* shorter than the calyx, stiff, consisting of 7-10 bracteoles connate below free above; *calyx* connate below free above; *sepals* bristly, lanceolate, with a gland at the back of each; *corolla* large, spreading, thickened below, very thin above; *capsule* globose, pointed, bristly; *seeds* nearly glabrous.

Type 1. Plants early. *Stem* comparatively short, stout, prickly, purple, side branches stout, arising near the base and remaining parallel to the main stem. *Stipules* purple. *Leaves* subcordate, simple, occasionally slightly lobed; margin purple, occasionally some purple colour on the veins both on the upper and lower surface; texture coarse; petiole purple. *Peduncle* purple. *Epicalyx* green with some purple. *Sepals* green with a few purple spots; apices green; central gland green with a red spot. *Corolla* yellow with a crimson eye, some purple colour diffused over upper part of petal. *Seedlings* stem dark red; petiole dark red; cotyledonary leaves red above green below.

Type 2. Plants early. *Stem* comparatively short, stout, green, side branches stout, arising near the base and remaining parallel to the main stem. *Stipules* green. *Leaves* subcordate, simple, occasionally slightly lobed; margin red; lamina and veins green; texture coarse; petiole green. *Peduncle* green. *Epicalyx* green. *Sepals* green; central gland green. *Corolla* yellow with a crimson eye. *Seedlings* stem, petiole and cotyledonary leaves green.

The collection at the India Museum contains specimens of *H. cannabinus* with simple leaves from Kyaukse, and other places in Burma and also from Bezwada, Madras, but it is impossible to say whether they belong to type 1 or to type 2.

Type 3. Plants fairly early, very robust, setting much seed. *Stem* tall, stout, prickly, red except the upper 6 or 7 inches which remain green. *Stipules* green. *Leaves* palmately divided into 3-7 (usually 5) lobes, a few are simple and subcordate, the upper leaves lanceolate, green; margins red; petiole red. *Peduncle* green.

Epicalyx green. *Sepals* green with a few red spots. *Corolla* yellow with a crimson eye. *Seedlings* somewhat small, stem red; petiole red; cotyledonary leaves green.

Type 4. Plants late, delicate, setting few seeds. *Stems* very tall, slender, prickly, purple with spiry thin branches on the upper two-thirds. *Stipules* purple. *Leaves* generally palmately divided, with 3-7 (usually 5) narrow lobes, a few leaves simple and subcordate, the upper ones are occasionally lanceolate, dark green with much purple colour on the veins on the upper and lower surface; margin purple; texture thin; petiole purple, purple patches often appearing on the leaves. *Peduncle* purple. *Epicalyx*, upper surface purple, under surface partly purple. *Sepals* green with many purple patches; apices purple; central gland green with a red spot. *Corolla* yellow with a crimson eye, much purple colour diffused over the petals especially on the under surface. The closed bud appears purple. *Seedlings* slender; stem tall and dark red; cotyledonary leaves small and dark red.

Type 5. Plants intermediate in habit between types 1 and 4, setting a moderate amount of seed. *Stem* stout, prickly, purple. *Stipules* purple. *Leaves* palmately divided with 3-7 lobes (usually 5), broader and lighter green than in type 4; veins purple, margin purple; texture thin but thicker than in type 4; petiole purple. The leaves of this type are green in comparison with those of type 4. *Peduncle* green with some purple spots. *Epicalyx* green below purple above. *Sepals* green with a few purple spots; apices green; central gland green with a red spot. *Corolla* yellow with a crimson eye, with purple slightly diffused into the petals. *Seedlings* stem dark red; petiole dark red; cotyledonary leaves dark red.

Type 6. Plants very early, tall, almost unbranched. *Stem* smooth, green, occasionally slightly reddish. *Stipules* green. *Leaves* green, palmately divided with 3-7 narrow lobes (usually 5), a few simple and subcordate, upper leaves lanceolate; petiole green. *Peduncle* green. *Epicalyx* green. *Corolla* yellow with a crimson eye. *Seedlings* somewhat small; stem red; petiole red; cotyledonary leaves green.

Type 7. Habit intermediate between that of types 1 and 4, with less branching than in type 8. *Stem* smooth, stout, green. *Stipules* green. *Leaves* palmately divided with 3-7 (usually 5) lobes, a few simple and subcordate, the upper leaves lanceolate; margin red; leaves large and coarse in texture; petiole green. *Peduncle* green. *Epicalyx* green. *Sepals* green. *Corolla* yellow with a crimson eye. *Seedlings* large; stem reddish; cotyledonary leaves green.

Type 8. Plants later than type 7, habit intermediate between types 1 and 4. *Stem* smooth, stout, green. *Stipules* green. *Leaves* palmately divided with 3-7 (usually 5) broad lobes, a few simple and subcordate, the upper ones lanceolate, quite green; margin red; leaves large and coarse; petiole green. *Peduncle* green. *Epicalyx* green. *Sepals* green. *Corolla* yellow with a crimson eye. *Seedlings*, large; stem quite green; cotyledonary leaves green.

The main points of difference between the types are summed up in the following pargraphs:—

Habit. The types differ considerably in habit and consequently in their suitability for fibre purposes. The tendency to branch can best be observed on the edges of the plots where the plants have most room. The inside plants do not branch so much but if there is a tendency to throw out side shoots, this is not entirely lost even if the crop is grown thickly.

Types 1 and 2, with simple leaves, are similar in habit and are dwarf forms compared with the rest, with a strong tendency to throw out from the base numerous stout branches which grow parallel to the main stem. Type 5 is an intermediate form between the above and types 7 and 8 in which the tendency to branching is less marked and in which the thin, short side shoots arise not at the base but more evenly distributed up the stem. Types 3, 4 and 6 are similar straight tall forms in which the side shoots of the edge plants are thin and weak, and in which practically no branching takes place in the interior of the plots. As far as long clean stems are concerned the last three types are the most suitable for fibre purposes.

Vegetative vigour and duration of growth. In the vigour and growth period of the eight types there are wide differences which are of importance from the economic point of view.

Type 4 is exceedingly delicate, very sensitive to waterlogging and sets very few seeds even when grown under the most favourable conditions. The growth period is very long and flowers only appear after the other types have ripened some seed. Germination is slow and the seedlings are small, delicate and very slender. In spite of its tall unbranched stems these defects render this form useless as a fibre plant in the plains. Type 5 shows similar defects but to a lesser degree.

Type 6 is the earliest of all the types and ripens its seeds and begins to dry up while the others are flowering. This fact combined with its general vigour and tall unbranched habit render it of use as a rapidly ripening fibre plant for growth in the *kharif*.

Type 3 is the most promising form from the point of view of general vigour and its capacity to grow and to set seed under comparatively unfavourable conditions. It is a mid crop form and corresponds in growth period to type 7 the common form of the plains.

Leaves. The types can be divided into two classes, one (types 1 and 2) with entire leaves and the other with palmately divided foliage in which the number of lobes is generally five. Sometimes in types 1 and 2 a few leaves are met with which show a tendency to form lobes, but this is rare and the leaves as a rule are uniform. In the class with divided leaves the foliage is not uniform. The early formed leaves on the main stem and on the side shoots are often entire while the inflorescence leaves are first trilobed and finally lanceolate. The tendency to produce entire leaves is not equally great in all the types. In type 3 many entire leaves are found and a large number of the inflorescence leaves are lanceolate. On the other hand, type 4 does not usually show either simple or lanceolate leaves.

The width of the lobes also differs, those in type 4 are very narrow and those in type 7 are the broadest. The difference in

the width of the lobes of the leaves is an important distinction between types 4 and 5.

There are also differences in the texture of the leaves. Types 1, 2, 7 and 8 have coarse thick leaves with a puckered surface, while the leaves of type 4 are very thin and flat. Thin leaves are also met with in types 3 and 5.

Colour. The most striking differences in these types are colour differences. Not only is both red and purple found, but the localisation of the colour varies in a very interesting manner. From the natural crosses it appears that the red colour is dominant but is diluted in the F_1 generation. Many pink stemmed plants have been selected, all of which split into purple stemmed, green stemmed and pink stemmed plants in the next generation.

In type 4 the colour of the leaf is a dark bronze green with a tendency for purple patches to appear as the leaf gets old. The corolla shows a purple eye and much purple colour diffused on the petals especially at the back. The capsules also show a good deal of purple colour. In the whole plant the chlorophyll is masked and the general appearance is purple.

In type 5 the purple colouration is not so intense. The lobes of the leaves are entirely green and are broader than in type 4. The plants are shorter and more robust and the flowers earlier. The general appearance is that of a purple plant with green leaves. It will be seen in Plate III that the colour in type 3 is red rather than purple and that this colour only reaches to within 6 or 7 inches of the apex. This occurs both on the main stem and on the side branches.

Transverse sections show that the colour in the purple varieties is due to a crimson coloured cell sap which fills the entire epidermal layer and also the outer layers of the cortex. On mounting a section in water the cell sap of some of the epidermal cells readily diffuses out, turns blue and temporarily stains the collenchyma which lies beneath the chlorophyll-containing cortex. In type 3 the cells with coloured sap lie scattered in the outer layers of the

cortex with a few in the epidermis, but there is no continuous ring of two or three layers of coloured cells as in the purple types. The upper portion of the stem is quite green to the eye, but, nevertheless, contains scattered coloured cells. In types 6, 7 and 8 the stems which are quite green while growing vigorously, turn red as the plant gets old and when the fruits are ripe the stem may be as red as in type 3. Diseased or stunted specimens often show the same phenomenon. In transverse section the coloured cells are found to be scattered in the cortex as in type 3.

There is a tendency for coloured patches to appear on the blade as the leaves get old. These patches are purple in the purple stemmed kinds and red in the green and red stemmed types.

Seedling characters. In the summary on page 17 it will be seen that the distinction between types 7 and 8 rests on the colour of the seedlings only as the mature plants are indistinguishable. The seedlings of type 7 have reddish stems which turn green when the plants grow up while the seedlings of type 8 have green stems. This curious difference in the seedlings is constant appearing every year.

There are differences between the seedlings and young plants of the rest of the types with one exception, namely, in the seedlings of types 3, 6 and 7 where they are somewhat similar. Types 1 and 5 are alike in the very early stages when the cotyledonary leaves are red on the upper surface. In a short time type 5 shows divided leaves those of type 1 remaining simple throughout. The characteristics of type 4 appear in the seedling stage, the cotyledons are small and the young stems tall and slender. Types 2 and 8 have green seedlings which can soon be distinguished, the former forming simple leaves only, the latter divided foliage. The seedlings of the first generation of crosses between green and purple kinds are pink in colour.

The significance of these seedling differences as well as those which appear in the early stages of growth are of great importance and are dealt with in the next chapter.

5. A POSSIBLE EXTENSION OF THE METHOD OF PURE LINE CULTURES.

The constant differences observed between the seedlings of the types of *H. cannabinus* are of importance from two points of view. In the first place, they render the production of uniform fibre and pure seed a comparatively easy matter. In the second place, and this is by far the more important, they suggest a method by which the system of pure line cultures can be applied to some extent to the improvement of plants like cotton in which a certain amount of natural crossing takes place and in which it is essential to preserve uniformity in any improved type.

Uniformity is of great importance in fibre plants. Not only is it necessary for the crop to ripen at the same time so that it can be cut and retted at once but also the quality of the fibre must be uniform. Branched and straight growing forms growing together do not give fibre of even length while a mixture of different types even if they ripen together gives a product of uneven quality. The immediate loss of quality which results from growing an improved type with a small admixture of other forms is, however, small compared with the consequences of this proceeding which are only to be seen in succeeding crops. Not only do the constituents of the mixture appear in the next generations but also new forms arise from crossing between the original constituents. The quality of the fibre rapidly changes and is not constant from year to year. Any improvement observed in the first year is soon lost and the quality rapidly degenerates.

The differences between the seedlings and young plants of the various types of this crop enable a pure culture to be maintained without much trouble. Most of the stray plants which arise from accidental admixture can be detected by the differences they show in the seedling stage. Any which escape the first rogueing disclose themselves before the crop is a foot high. No difficulty would be experienced in carrying out this work in practice as the ordinary labour is easily trained to the work. Indeed the boys if

left to themselves in thinning this crop always remove any seedlings which differ from the bulk of the culture. A little extra care in attending to a plot raised for the purpose of growing seed for distribution to cultivators is all that is necessary to keep the culture pure and to prevent any natural crossing. The same care devoted to plots grown for fibre would ensure an absolutely uniform and even sample. If, as we suspect, it is found that type 3 is superior in vigour of growth, in the length and straightness of stem and also in yield of fibre to the other types, the maintenance of this form in a pure condition on a seed farm will not be a difficult matter. If, however, no care is taken to keep the seed-plots pure it will readily cross with other types and its qualities will be quickly lost.

The significance of the above results are of great importance from the point of view of the improvement of crops in India. In the case of crops which are usually self-fertilized an improved type can often be obtained by the selection of single plants and the comparison of their offspring in succeeding generations. The quality of any such improved strain can be readily maintained by keeping the seed-plots pure by rogueing and by starting the culture afresh from a single plant when necessary. In attempting to apply this method of improvement to crops which cross difficulties at once arise on account of the contamination of the cultures by vicinism before the preliminary work can be completed. If, however, it is possible, as in the case of *H. cannabinus*, to detect by their seedling or early vegetative characters most of the aberrant plants which arise, the difficulties due to crossing can be greatly reduced in the early part of the work and entirely obviated when one type only is being grown for seed distribution. All that is necessary is to study carefully the seedling and vegetative characters of the selected type and to remove systematically everything that appears in any way different from this. All this must be completed before the first flowers appear so as to prevent crossing with undesirable types.

It is possible that a study of the seedling characters will be of use on cotton seed farms where it is essential to maintain the quality

of any improved type and to prevent deterioration arising from indiscriminate crossing. Some rogueing might be done in certain cases in the seedling stage and the process could be continued and completed before the time of flowering. Cook[1] in a recent paper has drawn attention to the desirability of weeding out aberrant plants in cotton cultures grown for seed when the maintenance of the quality of any improved type is aimed at. For this purpose he suggests the vegetative characters of the desirable kind should be carefully studied and that any plants differing in habit should be removed as quickly as possible.

[1] Cook, *Cotton selection on the farm by the characters of the stalks, leaves & bolls*, Circular No. 66, Bureau of Plant Industry, Washington, D.C., August 1910.

II. *HIBISCUS SABDARIFFA, L.*

1. Introduction.

This plant, the red sorrel of the West Indies and the Rozelle or Rouselle (corruption of Oiselle) of Madras is cultivated in India for a variety of purposes. Almost every part of the plant can be utilized. The stems yielded a strong silky fibre known to commerce as "Rozelle Hemp." The fleshy calyces, which have a pleasant acid taste, and a very attractive red colour are extensively used in jellies, chutnies and preserves. In the West Indies a cooling drink is also prepared from them. The seeds are useful in medicine and the leaves are employed for salads and curries. Recently a further method of utilizing this plant has been suggested, namely, the extraction of a yellow dye from the petals. Material was sent to England by the Officiating Reporter on Economic Products to the Government of India and was examined by Professor A. G. Perkin, F.R.S., but the report was distinctly discouraging and it seems unlikely that any success will be obtained.[1]

This species is cultivated all over India (except in the hills) and in Ceylon. It is also extensively cultivated in Jamaica for fibre and in the West Indies generally for the calyx. In India the plant is known under the vernacular names of *mesta, patwa, lal ambari, kempu.* The cultivation is simple. *H. Sabdariffa* takes somewhat longer to come into flower than *H. cannabinus*, but is much less sensitive to waterlogging and to defective aeration. It is sown as a *kharif* crop and harvested in November or December. The height of the plants varies with the cultivation but may reach 10′. They branch profusely, the branches arising from the base and remaining parallel to the main stem which is not much stouter

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[1] *Agricultural Ledger*, No. 2, 1908.

than the branches. The stems and branches are supple but not very rigid, and the plant is lusty rather than erect and has a tendency to sprawl.

The stems are retted in the same manner as those of *H. cannabinus*. The fibres are silky and fine, but apparently not so strong as those of *H. cannabinus;* the breaking strain of the latter is given by Wiesner[1] as 115 whereas that of *H. Sabdariffa* is only 89.

The following description of the fibre is taken from Dodge's *Descriptive Catalogue of the useful Fibre plants of the world.*

"A superb sample of this fibre was shown in the exhibit of British Guiana, W. C. E., 1893, which was accompanied by the stalks some 10 feet high, as straight and clean as jute stalks.

The fibre was equal, if not superior, to much of the jute which comes to this country. In my examination for award it was given the following rating: Length, 90 points; strength, 75 points; colour 80 points; average, 81·6."

Most of the descriptions and statements concerning *H. Sabdariffa* or Roselle refer to a plant with red stems and red calyces. In a few accounts mentioned is made of a variety with a white calyx but no description is given. It is sometimes said to be less acid than the red variety. No other forms are referred to in the literature. We have at Púsa isolated not only the red and the white varieties but two intermediate forms. These are partly red but in each the localization of the colour is different.

2. Pollination and natural cross-fertilization.

This species forms a striking contrast to *H. cannabinus* in the entire absence of natural cross-fertilization. Three varieties of Rozelle have been grown next to next at Púsa for four years and not a single instance of natural crossing has been observed. Seed from plants growing near the edges of the plots where the branches of two varieties interlaced was purposely chosen on two occasions

[1] Wiesner l. c

for growing on in the following year but in all cases these plants bred absolutely true and the progeny was uniform.

The flowers open late in the morning and close at midday, remaining open for not more than three hours. The stigmas are throughout flush with the opening of the staminal column and do not grow into the air as in the case of *H. cannabinus*. The filaments are very short and the anthers burst round the opening of the column. Self-pollination is favoured by these arrangements and the completion of the process is brought about by the closing of the flower. (Plate V.) It will be seen that the differences in the pollination mechanism between this species and *H. cannabinus* are very slight but sufficient, in the present case, to prevent practically any cross-fertilization.

The peduncle of the flower is longer and much more supple than in *H. cannabinus*. Emasculation and artificial cross-fertilization present no difficulties and this species also sets seed fairly readily under bag.

3. Description of the varieties.

Four different forms in all have been isolated by us and these have bred true. As the differences are very distinct and are of a morphological nature rather than agricultural, we have formed the following four varieties:—

1. Var. *ruber*.

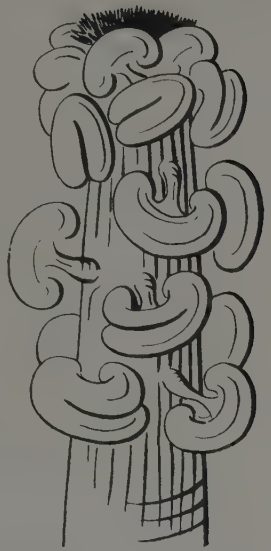
Stem and petiole entirely red. pulvinus red, calyx red, flowers on withering turn pink.

2. Var. *albus*.

Stem and petiole green. pulvinus green, calyx yellowish, flowers on withering remain yellow.

3. Var. *intermedius*.

Stem and petiole green with some red, pulvinus red, calyx yellowish green. flowers on withering remain yellow.



THE POLLINATION MECHANISM OF H. SABDARIFFA.

PLATE V.

4. Var. *Bhagalpuriensis.*

Stem and petiole green with some red, pulvinus green, calyx green with red splashes, slightly more obtuse and more twisted than in any of the other three varieties, flowers on withering turn pink.

With the exception of the slight difference in the form of the calyx in var. *Bhagalpuriensis* these four varieties are absolutely identical in all morphological and agricultural characters. They flower at the same time, grow to the same height and are equally robust. The only difference between them is one of colour.

The existence of two intermediate forms with small amounts of colour, quite differently located appears to indicate that the factors concerned in the occurrence of colour in this species are very numerous. Besides the main distinctions given in the synopsis of the varieties many smaller differences in the localisation occur. It is interesting to note that in the var. *intermedius* in which the flower resembles that of var. *ruber* in every respect, the corolla nevertheless remains yellow on withering instead of turning pink. In var. *Bhagalpuriensis* where there are differences in the colour of the pollen and of the eye the corolla turns pink like that of var. *ruber*. The tendency of the petal to change colour on fading would appear to be a definite character.

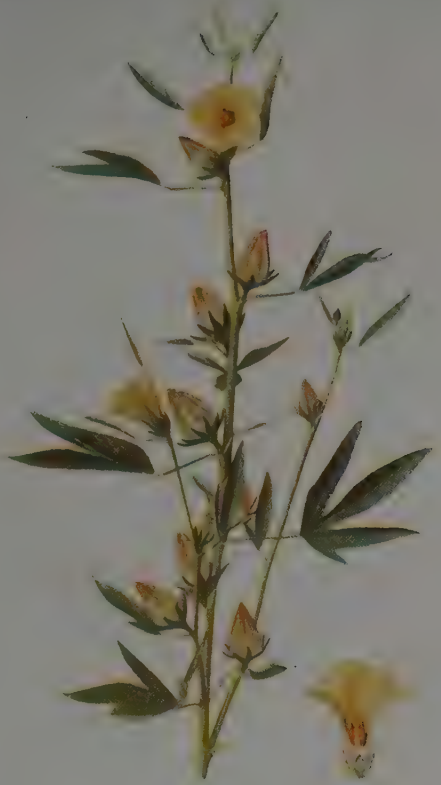
In the following table all the differences between the two intermediate varieties are given.

Var. *intermedius*	Var. *Bhagalpuriensis.*
Stem. Green with two triangular red patches, one in the leaf axil and one below the petiole	Green with one triangular red patch in the axil of the leaf.
Pulvinus. Deep red.	Green
Calyx. Yellowish green with green apices, form as in vars. *ruber* and *albus*, gland on sepal yellowish green with a red spot.	Bright green with splashes of red, apices more twisted, shape more obtuse than in var. *ruber*, gland on sepal yellowish green without spot.
Corolla. Eye deep crimson, limb remains yellow on withering.	Eye slightly less crimson, limb turns pink on withering
Pollen. Deep orange.	Orange-yellow.

The occurrence of var. *intermedius* is interesting. In 1906, a sample of seed of Rozelle was grown in the Botanical area at Púsa. It was noticed that this contained three or four white plants and these were harvested separately and sown next year. Among the plants so raised was *one* plant of var. *intermedius*. This plant bred true in the following and all succeeding years. It is difficult to account for the occurrence of this single intermediate plant among the white unless it be a mutation form. Roselle had never been grown before in the Botanical area and therefore admixture from seed lying in the ground was impossible. Another possibility, that this was the only surviving plant of an intermediate parent wrongly classed as white in the previous year is highly improbable. Each plant sets a great deal of seed, germination was good and no great mortality among the seedlings occurred. It is also unlikely that it is a natural cross breeding parthogenetically as emasculated flowers of this species have so far failed to set seed under bag. Unfortunately as the seed of the white plants was mixed before sowing, it is now impossible to state definitely that it is a mutation form. This variety has never been met with anywhere else and has so far not made its appearance again in cultures of var. *albus* at Púsa.

Var. *Bhagalpuriensis* was found in the neighbourhood of Bhagalpur. A number of plants, all similar, were found growing at the edge of a field on the Government Farm at Sabour. Seed of single individuals was collected and grown at Púsa this year, when the progeny was uniform and like the parent.

As it seems possible that cross-breeding experiments may give interesting information on the Mendelian factors regulating the localization of colour in this species, all these varieties have been crossed among themselves. They afford particularly valuable material for this work as they are all alike morphologically, ripen at the same time, are easily grown, set seed under bag and also as far as we have observed, do not reproduce parthenogenetically and do not cross when grown next to next. The first generation



Var. *albus.*

Var. *ruber.*

HIBISCUS SABDARIFFA, L.

PLATE VI.

of the cross between var. *ruber* and *albus* was grown this year and resembled the red parent in every respect.

It has already been stated that as regards agricultural characters there is no difference between the four varieties. For culinary purposes, however, the red one is decidedly the most useful both on account of its attractive colour and also because the calyx is less fibrous and harsh than in some of the varieties. The calyx of var. *Bhagalpuriensis* is scarcely edible on account of its tough stringy nature.

The four varieties are represented in Plates VI and VII and a detailed description of each is given below.

Shrub erect, annual. *Stem* glabrous, unarmed but with emergences at intervals, much branched with long branches arising near the base. *Stipules* generally simple and linear, sometimes bilobed. *Leaves* lobed, upper ones simple and lanceolate, with a pulvinus at the base of the blade, and a gland on the midrib of leaf; margin serrate; petiole often with a line of hairs on the upper surface. *Peduncle* solitary and axillary. *Epicalyx* united at the base and adnate to the calyx; bracteoles 8-12 linear. *Calyx* connate below free above; sepals 5-7, accrescent, fleshy, with a gland on the midnerve of each. *Corolla* yellow spreading, aestivation imbricate. *Capsules* ovoid, pointed, villous, shorter than the calyx. *Seeds* reniform, subglabrous.

VAR. *ruber*.

Stem dark red. *Stipules* dark red. *Leaves* green with some red colour on the lower surface of the veins, sometimes also on the upper surface; gland on the midrib colourless; petiole dark red except for a narrow strip on the under surface; pulvinus red. *Peduncle* red. *Epicalyx* red. *Sepals* red; central gland on midnerve greenish. *Corolla* yellow, with a deep crimson eye, turning a deep orange pink on withering. *Stamens* staminal tube red; pollen and anthers deep red. *Stigmas* red. *Seedlings* stem green with some red below the cotyledonary leaves; petiole red on the upper surface, green below; leaves green. (Plate VI.)

VAR. *albus.*

Stem green. *Stipules* green. *Leaves* green, no red colour on the veins; pulvinus green; petiole green. *Peduncle* green. *Epicalyx* green. *Sepals* yellowish green; apices yellow when ripe. *Corolla* yellow with colourless eye. *Staminal* tube white showing up the yellow pollen. *Stigmas* white. *Seedlings* stem, petiole and colyledonary leaves green. (Plate VI.)

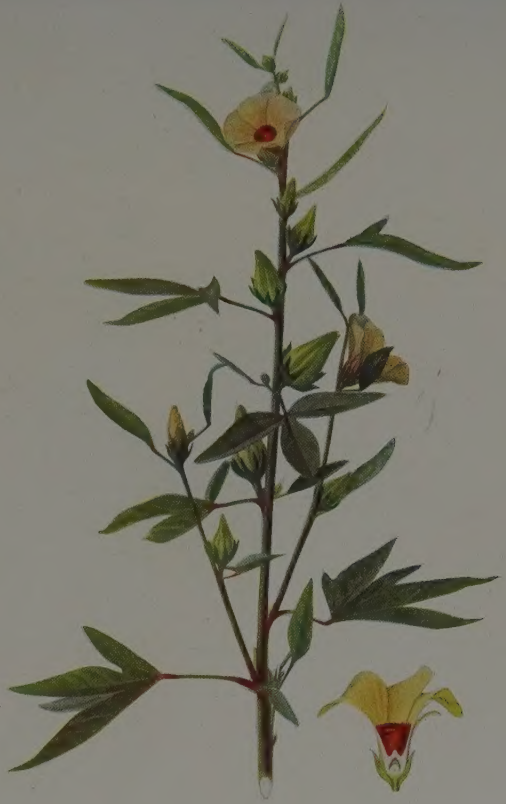
VAR. *intermedius.*

Stem green with some diffused reddish colour and with deep red triangular patches both in the axil of the leaves and also immediately below the petiole. *Stipules* green. *Leaves* green with some reddening on the upper surface of the veins; pulvinus red. *Peduncle* green. *Epicalyx* green. *Sepals* yellowish green; apices green when ripe, a red spot in the central gland on the midnerve. *Corolla* yellow with a deep or crimson eye, remaining yellow on withering. *Stamens* staminal tube red; pollen deep orange. *Stigmas* red. *Seedlings* indistinguishable from those of var. *ruber.* (Plate VII.)

VAR. *Bhagalpuriensis.*

Stem green with some diffused red colour and a deep red triangular patch in the axil of the leaves. *Stipules* green. *Leaves* green, veins green; petiole green with a certain amount of diffused redness, pulvinus green. *Peduncle* green. *Epicalyx* green. *Sepals* bright green with splashes of red; central gland with a red spot. *Corolla* yellow with a crimson eye which is less deeply crimson than in var. *intermedius,* orange pink when faded. *Stamens* staminal tube red; pollen less deeply orange than in var. *ruber* and *intermedius. Stigmas* red. (Plate VII.)

Var. *Bhagalpuriensis.*



Var. *intermedius.*

HIBISCUS SABDARIFFA, L.

PLATE VII.